Interim Report
Unbonded Concrete Overlays
Minnesota Experience

Minnesota Department of Transportation
Engineering Services Division
Office of Materials and Research
Physical Research Section

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Attachment 2 - Draft - Mn/DOT Unbonded Concrete Overlay Design Procedure

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Background

In an attempt to find new, cost effective pavement rehabilitation techniques Mn/DOT has constructed ten unbonded concrete overlays since 1977. The design and construction of each successive project built on the experiences gained from the previous project. Unbonded concrete overlays have now developed to the point where Mn/DOT feels it is appropriate to review these past experiences and develop policy on further construction of these projects. Sufficient time has also elapsed to evaluate the long term performance of specific projects and unbonded overlays in general.

Literature Search

A literature search was conducted through Mn/DOT's Library. The review of the papers collected has pointed out several interesting features:

1. Joint spacings of 15 feet (4.57 m) or less are performing better. (Reference 3)

2. Maintaining an L/l of between 6 and 7, where L is the slab length (in) and l is the radius of relative stiffness (in). (Reference 1)

3. Unbonded overlays with or without dowels fault very little. Dowels are not recommended when traffic produces less than 0.8 million 18-kip (8200 kg) ESAL per year. (References 1 & 3)

4. Joints in the overlay should be mismatched by 3 feet (0.91 m) minimum from the joints in the underlying pavement. (References 1, 3 & 4)

5. The largest joint movements corresponded to the location of a joint in the overlaid pavement. Large movements can also be an indication of an ineffective bond breaker. (Reference 4)
6. The load transfer efficiency of the dowelled joints in unbonded overlays was 29% better (based on FWD data) than on a conventional new recycled pavement structure. (7 inch (17.8 cm) overlay vs 9 inch (22.9 cm) PCC pavement) Mid-slab deflections were also 25% less in the overlay. (Reference 4)

7. Severely deteriorated cracks and joints should be repaired full depth to minimize premature failures of the overlay. (Reference 4)

8. Bond breaker depth should be a minimum of 1 inch thick hot mix asphalt. Slurry seals are effective only when faulting in the existing slab is not significant. (Reference 1)

9. Thermal stresses are critical in unbonded concrete overlays because of the very stiff support from the existing slab. (Reference 1)

History

Various forms of concrete overlays have been constructed in Minnesota in the past. However, documentation on the performance of these early projects is often difficult to find. A concrete overlay was placed on TH 12 east of St. Paul in 1955 (SP 6210-13 & 8203-18). The original 9-7-9 (23-18-23 cm), 20 foot (6.1 m) wide pavement was constructed in 1928. This overlay consisted of a variable thickness gravel base (0 - +18 inches (0 - 46 cm)) followed by a 24 foot (7.32 m) wide, 9 inch (22.9 cm) thick concrete pavement. There were also sections of 5 inch (13 cm) thick bonded concrete overlay and sections where a sand seal was used between the 5 inch (13 cm) thick overlay and the old pavement. Little is known about the overall performance of this pavement except that it did exhibit some early transverse cracking due to frost heave. This pavement was removed when I-94 was constructed in the 1980's. Another concrete overlay was placed on TH 169 between St. Peter and Le Sueur under SP 5209-22 in 1967. In this 7 mile (11.3 km) project, a 9-7-9 (23-18-23 cm), 20 foot (6.1 m) wide, concrete pavement was overlaid with 6 inches (15.2 cm) of concrete 24 feet (7.32 m) wide. A 4 mil (0.1 mm) polyethylene sheet was used as a bond breaker with variable success. This project was overlaid within 8 years with bituminous due to excessive D-cracking from the Bryan Redrock aggregate, a dolostone found near Jordan, Minnesota.

The first true unbonded overlay was constructed as a research test section approximately 0.64 miles (1.03 km) long on TH 71 north of Olivia, Minnesota. The first complete unbonded overlay project was not constructed until 1985 on TH 212 in Glencoe. Since 1986, eight
unbonded overlays have been constructed statewide, all on the Interstate System. The thickness was designed for 35 year ESAL’s. The following paragraphs will provide a brief description of each project and what we learned from each.

TH 71
SP 3411-41 & 6509-12
Year Built - 1977

Location - This project begins north of Olivia at RP 103.045 and extends north to RP 103.685. (0.6 miles, 1.03 km)

Original Conditions - This segment of undivided highway was originally graded and surfaced in 1947. The subgrade was reconditioned with granular material to a depth of 30 inches (0.76 m). The original concrete pavement was 22 feet (6.7 m) wide, no dowels, 9-7-9 (22.9 cm - 17.8 cm - 22.9 cm), with 15 foot (4.57 m) joint spacing.

Soils/Drainage - The mainline base consists of 8 inches of crushed stone, gravel and slag. The subgrade is an A-6 silty-clay.

Traffic - ADT 4950 (1997), 12.3% Trucks. ESAL’s through 1991 870,000. Twenty year design EASL’s were 2,260,000.

New Construction - The existing pavement was overlaid with 1 inch (2.54 cm) of 2331 Modified plant mixed bituminous 28 feet (8.5 m) wide. The JPCP is 24 (7.32 m) feet wide, 5.5 inches (14 cm) thick, joints are skewed at a ratio of 6:1, 15.5 foot (4.72 m) effective random spacing (13, 16, 14, 19 feet), dowels are 0.75 inch (1.9 cm) X 14 inches (36 cm) long spaced at 1.0 ft (0.305 m) c-c with 2.5 inches (6.35 cm) cover to surface and 2 inch (5.08 cm) cover to bottom. The project did not include any edge drains.

Present Condition - This project was last surveyed in 1991. The SR = 3.6, PSR = 3.1 and PQI = 3.4. The 500 foot PMS rating section did not include the test section but it is considered to be representative. A more detailed analysis will be completed on the data retrieved with the PaveTech equipment at a later date.

Lessons Learned - Since this was the first unbonded overlay the most important item learned was that they could be built successfully. The more significant individual items we learned include:

1. No repairs were completed on the existing concrete before the overlay was constructed. This was due primarily to the fact that the section of pavement selected for the overlay was in relatively good condition. Pavement
should have been cleaned prior to placement of stress relief layer with power sweeping and air blowing.

2. The 5.5 inch (14.0 cm) overlay may have been too thin. Mid-panel cracks have developed in the overlay, possibly reflected cracks in an area of weak soils.

3. The bituminous stabilized stress relief layer has stripped. (9% AC, 200-300 penetration, mortar sand)

4. Overlay pavement could be successfully cantilevered over the existing pavement.

5. Basic constructability of an unbonded overlay did not present a problem.

6. Started to use the lime slurry white wash about half way through the project to reduce the temperature of the stress relief layer before concrete placement.

TH 212
8P 1012-16 & 4310-40
Year Built - 1985

Location - This project is east of Glencoe on the Westbound lanes from RP 121+00.173 to RP 128+00.580. (7.4 miles, 11.9 km)

Original Conditions - In 1966 the WB lanes were graded and surfaced with 9 inch (22.9 cm) thick, 24 foot (7.32 m) wide pavement. Severe "D" cracking developed due to the use of Bryan Redrock. Extensive corner breaks and loss of structural panel integrity was occurring. The 1983 Condition Survey showed a SR of 2.9, a PSR of 1.6, and a CR of 2.3.

Soils/Drainage - The subgrade soils for this segment consisted of clay, clay loams and loams.

Traffic - ADT for the year 2010 is 7030. ESAL’s through 1991 1,100,000. Twenty year design CESAL’s were 5,385,000.

New Construction - In 1985 the westbound lanes were overlaid with 1.5 inch (3.81 cm) thick, 30 feet (9.14 m) wide of Mn/DOT Specification 2331M bituminous stress relief layer. It was thicker in some areas in order to improve the crown and transverse gradient of the concrete overlay. The plain concrete overlay was 7 inches (17.8 cm) thick and 27 feet (8.23 m) wide of plain concrete with doweled joints. The stress relief layer used an aggregate gradation meeting Mn/DOT Specification 3128 Mortar Sand with 8% AC by weight having a 200/300 penetration. The effective random joint
spacing was 15 feet (4.57 m). Dowels were 1 inch (2.54 cm) diameter and 15 inches (38.1 cm) long. Edge drains were not incorporated into this project.

Present Condition - The 1991 Condition Survey resulted in a PSR of 3.8 an SR of 4.0 and the PQI for this segment was 3.9.

Lessons Learned -

1. Stress relief layer reduced friction to the point that, every eighth joint opened as much as 1.5 inches (3.81 cm). It took about a year for all the intermediate joints to crack and for the crack widths to even out. The contractor was allowed to drive on the stress relief layer. The current condition of the stress relief layer is unknown.

2. The stress relief layer was whitewashed with a mixture of hydrated lime and water two hours prior to placing the concrete overlay. Its intent was to reduce the surface temperature of the stress relief layer thereby enabling the concrete to cure properly.

3. Loose spall and debris was removed by brooming and then open joints, cracks, and other depressions were filled with the stress relief layer material by tight blading.

4. Severely broken panels were to be removed and replaced with Class 5 aggregate base material, however no surface repair or other remedial work was required.

5. Use of 27 foot (8.23 m) wide panels with rumble strips has performed satisfactory.

I 90
SP 5380-86
Year Built - 1986

Location - Eastbound and Westbound lanes, Near Adrian, MN from East end of bridge over C&NW railroad to one mile east of CSAH 13. (8.7 miles, RP 25+00.965 - 34+00.709, 8.7 miles (14.1 km))

Original Conditions - This segment was originally graded and paved in 1968 with 6 inches (15.2 cm) of aggregate base and 8 inches (20.3 cm) of continuously reinforced concrete pavement (CRCP) 24 feet (7.32 m) wide. A 1984 Condition Survey showed that 100% of the cracks exhibited D-cracking. The PSR was 3.7, the SR 3.4 and the CR 3.5 for the eastbound and the PSR was 4.0, the SR 3.5 and the CR 3.7 for the westbound.
Soils\Drainage - Clay loams, some silt pockets, sandy clay loam, sandy loam, and high water table were present.

Traffic - Traffic for the year 2010 is forecast to have an ADT of 16,770. ESAL's through 1991 1,050,000. Twenty year design CESAL's were 9,700,000.

New Construction - The 24 foot (7.32 m) wide eastbound & westbound lanes were overlaid with 1 inch (2.54 cm) thick and 31 feet (9.45 m) wide of Mn/DOT Specification 2331 bituminous stress relief layer. The JRCP overlay consisted of 8.5 inch (21.6 cm) thick, 27 foot (8.23 m) wide reinforced concrete with doweled, skewed, joints at joint spacing of 27 feet (8.23 m). Edge drains were installed on this project. The edge drains were added prior to the stress relief layer on the westbound and placed after on the eastbound. Dowel bars were 18 inches (46 cm) long and 1.25 inch (3.18 cm) diameter.

Type 1 joint repair (E4D) was completed on 50 locations on the westbound and 29 locations on the eastbound. Type 2 and 3 joint repair (steel plates over ruptures and previously repaired joints) was done at 34 locations, all on the westbound lanes. Type 4 joint repair (4 inch (10.2 cm) relief joint) was completed at 7 locations on the west end of the project and 13 locations on the east end of the project. It was discontinued because of excessive curling.

Present Condition - The 1990 Condition Survey had the following ratings:

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<th>SR</th>
<th>PQI</th>
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<tr>
<td>Eastbound</td>
<td>3.5</td>
<td>4.0</td>
<td>3.7</td>
</tr>
<tr>
<td>Westbound</td>
<td>3.7</td>
<td>4.0</td>
<td>3.8</td>
</tr>
</tbody>
</table>

Lessons Learned -

1. The gradation of the stress relief layer was modified to 100% passing the #4 and 2 - 15% passing the #200 with 8.0 to 5.0% asphalt cement by weight.

2. A two foot wide, 16 gauge sheet metal was planned to be placed over all transverse cracks, joints and repairs. It was difficult to keep in place and was discontinued on the eastbound lanes.

3. Some transverse joints opened up very wide the first fall, 2-4 inches (8.1 - 16 cm) in places. Cores indicated that the joint seals and the stress relief layer has failed over many of the cuts (about 400 feet (122 m) c-c) in the CRCP. Adjacent joints were not
cracked. The rest of the project had larger joint openings (but perhaps not yet at failure) every third, fourth or fifth joint. This also included the shattered concrete and gravel base areas to some degree. The 41 large openings on the westbound were next to the E-8 joints, and only 8 to 10 large openings on the eastbound. This led to sawing deeper, t/3 on future projects. It also led to shorter, 15 foot (4.57 m) effective random joint spacings (13-16-14-17).

4. Cutting of the existing CRCP for relief joints caused the pavement to move excessively, approximately 2 inches (5.08 cm) and curl. This practice was discontinued after twenty joints were constructed.

Special Report - Construction Technology Laboratories, Inc. of Skokie, IL. conducted a field evaluation of this unbonded concrete overlay and wrote a report which was dated May 1988 (Reference 5). The objectives of the study were to perform load testing of the existing and overlaid pavement and use the data to determine the applicability for verifying mechanistically based design procedures for unbonded concrete overlays. The report came to the following conclusions:

1. The measured stresses and deflections in the concrete overlay were significantly lower than anticipated.

2. The measured stresses and deflections are significantly lower in an overlay when compared to a single layer concrete pavement of equal thickness.

3. The study results indicate that the theoretical thickness design procedure previously developed for unbonded concrete overlays is practical and can be used to compute required unbonded overlay thickness.

I 35
SP 1380-53 & 5880-129
Year Built - 1987

Location - Northbound and Southbound lanes from 2.1 miles north of Harris to a point 2.02 miles north of Chisago-Pine County Line. (8.3 miles, (13.4 km), RP 154+00.837 - 163+00.168)

Original Conditions - In 1969 the original roadway was graded and surfaced with JRCP, 9 inch (22.9 cm) thick and 24 feet (7.32 m) wide. Dowel bars were used with a joint spacing of 39 feet (11.9 m). Neoprene was used for the joint sealant. A 1985 Condition Survey showed a PSR of 3.7 a SR of 2.9 and a CR of 3.3, with the most common defects being spalled joints and cracked panels.
Soils/Drainage - Brown clay loams and clay with many silt pockets; high water table exists on length of segment.

Traffic - The AADT is projected to be 17,900 for the year 2010. A total of 923,000 ESAL's have accumulated through 1991. Twenty year design CESAL's were 6,960,000.

New Construction - Both the northbound and southbound 24 foot (7.32 m) wide lanes were overlaid with 1 inch (2.54 cm) thick, 30 foot (9.14 m) wide of Mn/DOT specification 2331M bituminous stress relief layer. The JPCP overlay was 8 inches (20.3 cm) thick, 27 feet (8.23 m) wide, with skewed, doweled joints at a random effective joint spacing of 15 feet (4.57 m). The dowels were 1 inch (2.54 cm) diameter and 18 inches (46 cm) long. Retro-fit edge drains were placed on the entire segment.

Present Condition - The 1992 Condition Survey had the following ratings:

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<td>Southbound</td>
<td>3.8</td>
<td>4.0</td>
<td>3.9</td>
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Some isolated longitudinal cracks have been observed in this pavement. These cracks will be further investigated with the data obtained with the PaveTech.

Lessons Learned -

1. The new transverse joints were specified to be placed a minimum of 3 feet (0.91 m) away from a joint or crack in the existing pavement.

2. The design required the use of mini-weep drains (interceptors) at each pavement joint and major cracks in the existing pavement to make a positive connection with the new edge drains.

I 90
SP 6780-74
Year Built - 1988

Location - Eastbound and Westbound lanes at Luverne, MN from Rock River at Luverne to Rock-Nobles County Line. (7.1 miles, (11.4 km), RP 13+00.292 - 20+00.409)
Original Conditions - This segment of I-90 was originally graded and paved in 1966 with 9 inch (22.9 cm) thick, 24 feet (7.32 m) wide jointed, doweled 39 foot (11.9 m) long reinforced concrete panels. The concrete mix utilized Hallet/Luverne aggregate which has since been linked to pavements highly susceptible to "D" cracking. The pavement exhibited a high occurrence of "D" cracking. The 1987 Condition Survey had the following ratings:

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<td></td>
<td>3.0</td>
<td>1.1</td>
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</tr>
<tr>
<td></td>
<td>3.3</td>
<td>1.3</td>
<td>2.1</td>
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<tr>
<td>Westbound</td>
<td>3.0</td>
<td>1.1</td>
<td>1.8</td>
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Soils\Drainage - Clay loam, silty loam, very high ground water levels (1.3 - 5.9 feet (0.4 - 1.8 m) below inplace finished surface), and shallow ditches.

Traffic - The AADT is 9513 for the year 2007. ESAL's through 1991 were 670,000. The twenty year design CESAL's were 9,590,000.

New Construction - This segment was overlaid with 1 inch (2.54 cm) thick, 31 feet (9.45 m) wide of Mn/DOT specification 2331M bituminous stress relief layer. The JPCP overlay was 8 inches (20.3 cm) thick, 27 feet (8.23 m) wide, with doweled joints including 15 foot (4.57 m) random effective joint spacing over the existing 24 (7.32 m) foot wide pavement. The dowels were 15 inches (38 cm) long and had a 1 inch (2.54 cm) diameter. "French mini" drains (interceptors) were also provided for on the overlay sections at all joints and major cracks. Edge drains were installed on this project. In addition, 1/2 mile (0.8 km) of various test sections were also constructed on this segment and they included the following:

1. A 1 inch (2.54 cm) thick minimum open graded bituminous stabilized drainable section to replace 1 inch (2.54 cm) thick dense graded bituminous stress relief layer.

2. A test section in which a drainable material (prefabricated "fin-type" drain is placed in the dowel basket area.

3. A test section without "French mini" drains (interceptors).

4. A 1 mile (1.61 km) long bituminous overlay section consisting of 1 inch (2.54 cm) thick (2361) wear, 2 inch (5.08 cm) thick (2331) binder and 3 inch (7.62 cm) thick (2331) base.
5. A test section with 8 inch (20.3 cm) thick, 27 feet (8.23 m) wide reinforced concrete overlay with 27 foot (8.23 m) joint spacings and load transfer.

6. A test section in which the dowels are omitted.

7. A test section of crushed quartzite stress relief layer, not stabilized.

Present Condition - The 1990 Condition Survey revealed the following:

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<tr>
<td>Westbound</td>
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<td>4.0</td>
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Lessons Learned -

1. Minimum contraction joint depth of the green sawing over the dowels shall be 1/3 the thickness of the concrete pavement.

2. The open graded bituminous stabilized stress relief layer was stable, and provided a good paving platform.

3. We expect to learn much more from the various test sections on this project once the data taken with the PaveTech is analyzed.

I 90
SP 6780-82
Year Built - 1990

Location - Westbound lanes, near Beaver Creek, from 128 feet (39.0 m) west of Bridge 67805 to East Rock County Line. (9.2 miles, (14.8 km) RP 003+00.925 – 013+00.157)

Original Conditions - This segment was originally graded and paved in 1964 with 9 inch (22.9 cm) thick, 24 foot (7.32 m) wide, reinforced concrete containing highly "D" crack susceptible aggregates (supplied by Hallet/Luverne). The panels were 39 feet (11.9 m) long with skewed joints. The Condition Rating for 1988 resulted in a PSR of 3.1 a SR of 1.1 and a PQI of 1.8.

Soils/Drainage - The soils included, weak clays, clay loams, in an area with a high water table.
Traffic - The AADT for the year 2010 is 17,900. The ESAL's accumulated through 1991 were 270,000. The twenty year design CESAL's were 8,625,000.

New Construction - The 24 foot (7.32 m) wide westbound lanes were overlaid with 1 inch (2.54 cm) thick, 33 foot (10.1 m) of 2211A open graded base stress relief bituminous layer. The JPCP overlay was 8 inches (20.3 cm) thick, 27 feet (8.23 m) wide with doweled joints at a 15 foot (4.57 m) random effective joint spacing. The dowels were 15 inches (38 cm) long and had a 1 inch (2.54 cm) diameter. Edge drains were placed at a minimum depth of 24 inches (61 cm) from the top of the finished concrete slab.

Present Condition - A 1991 Condition Survey resulted in a PSR of 3.3 a SR of 4.0 and a PQI equal to 3.6.

Lessons Learned -

1. The widened stress relief layer from 31 to 33 feet (9.45 to 10.1 m) provided a more stable platform for the tracked paver to drive on.
2. The 2211A open graded stress relief layer provided no real constructability problems, was stable and provided better drainage characteristics.

I 90
SP 5380-95 & 99
Year Built - 1991

Location - Westbound lanes, near Worthington, from one mile (1.61 km) east of CSAH 13 to 0.2 miles (0.32 km) west of TH 60. (10.3 miles, (16.6 km) RP 34+00.709 - 44+00.028)

Original Condition - This segment was originally graded and paved in 1969 with 8 inch (20.3 cm) thick, 24 foot (7.32 m) wide, with continuously reinforced concrete which utilized a highly "D" crack susceptible aggregate supplied by Hallet/Luverne. In 1985 some of the shoulders were milled & overlaid in order to preserve shoulders until the roadway was improved. In 1987 edge drains were placed on this segment. A maintenance contract placed bituminous spot overlays throughout this segment in 1989. The section was a severe maintenance problem due to "D" cracking. In 1980 alone 50 blow-ups and 100 cracks were repaired. A 1988 Condition Survey for the westbound lane revealed a PSR of 3.7, a SR of 2.0, and a PQI of 2.7. The survey also showed that close to 100% of the pavement surveyed exhibited "D" cracking.
Soils/Drainage - Mostly clay loams, 2 - 4.5 foot (0.61 - 1.37 m) granular subcut corrections placed during original grading, and inplace edge drains.

Traffic - ADT for the year 2010 is 8150. ESAL's through 1991 were 60,000. The twenty year design CESAL's were 8,623,000.

New Construction - The 24 foot (7.32 m) wide westbound lanes were overlaid with 1 inch (2.54 cm) thick, 33 foot (10.1 m) wide of open graded stabilizing base (Mn/DOT Spec. 2211A) bituminous layer. The JPCP overlay was 8 inches (20.3 cm) thick, 27 foot (8.23 m) wide with doweled joints at 15 foot (4.57 m) effective random joint spacing. The dowels were 15 inches (38 cm) long and had a 1 inch (2.54 cm) diameter. Additional 4 inch (10.2 cm) diameter edge drains were also placed.

Present Conditions - Data not yet available.

Lessons Learned -

1. Hold downs for dowel baskets were placed a minimum of 1 inch (2.54 cm) into the concrete surface. This made the dowel basket more stable under loads during paving operations.

TH 52
SP 5507-47
Year Built - 1992

Location - Northbound and Southbound lanes, near Rochester, from 0.5 miles (0.80 m) south of Jct I-90 to Jct TH 63. (5.6 miles, (9.01 km) RP 45.9 to 51.9)

Original Condition - The segment from RP 45.9 to 47.5 was graded and paved in 1971 with 8 inches (20.3 cm) of concrete over 5 inch (12.7 cm) of Class 5 aggregate base. The 24 foot (7.32 m) wide panels were not doweled and had a joint spacing of 27 feet (8.23) (RP 45.9-46.7) and 20 feet (6.1 m) (RP 46.7-47.5). The segment from RP 47.5 to 51.9 was graded and paved in 1976-78 with 8 inches (20.3 cm) of concrete over 5 inch (12.7 cm) of Class 5 aggregate base. The 27 foot (8.23 m) wide panels were also not doweled and had a joint spacing of 15 feet (4.57 m). In 1984 most of the southerly 1.6 miles (2.58 km) of the entire segment was planed and resealed.

All of the pavement was faulted 0.25 - 0.50 inches (0.64 - 1.27 cm) at the transverse panel joints. Curling and warping were also commonplace and provide for a rough ride. The segment that was

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planed and resealed in '84 had since faulted and is spalling. The 1991 Condition Ratings for the overlaid pavement were:

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</table>

Soils/Drainage - Subgrade soils consist of Silt Loams, Clays, and Ledge Rock. The design "R" value was 12. The twenty year design CESAL's was 9,921,000.

Traffic - Traffic for the year 2012 is forecasted to be 10,450 (Design Lane AADT).

New Construction - The segment was overlaid with 1 inch (2.54 cm) thick Permeable Asphalt Stabilized Stress Relief Course (Mn/DOT Spec. 2331) 33 feet (10.1 m) wide. The JPCP overlay was 8 inches (20.3 cm) thick, 27 foot (8.23 m) wide with doweled joints at 15 foot (4.57 m) effective random joint spacing. The dowels were 15 inches (38 cm) long and had a 1 inch (2.54 cm) diameter. Edge drains and Subsurface Drains were installed under this project.

Present Condition - Data not yet available.

Lessons Learned -

1. Stress relief layer needed to be placed in two lifts, up to 2 inches (5.08 cm) thick, to cover the severe faulting.

I 90
5580-64
Year Built - 1992

Location - Eastbound lanes, Olmsted County, from 0.3 miles (0.48 km) east of Jct TH 63 to 1.7 miles (2.74 km) east of C.S.A.H. 19. (12.2 miles, (19.6 km) RP 210.6 - 222.8)

Original Condition - This segment was originally graded and paved in 1970-71 with 6 inches (15.2 cm) of Class 5 aggregate base and 9 inches (22.9 cm) thick, 24 feet (7.32 m) wide of reinforced concrete with skewed transverse contraction joints at 27 foot (
8.23 m) spacing. In 1978 a Bituminous Shoulder Wedge and Shoulder Fog Seal project was let and completed.

The pavement was 50 - 100% D-cracked and most transverse joints were severely spalled and patched with bituminous. The 1990 Condition Ratings resulted in a PSR of 2.5, a SR of 0.8 and PQI of 1.4. Five reasons were given why an unbonded overlay was requested for this segment of I-90 and they were:

1) speed and ease of construction  
2) unstable subgrade soils (silty)  
3) D-cracked aggregate  
4) inplace shallow ditches (1-2 ft. in median)  
5) recommended by Minnesota Interstate Pavement Management Plan

Soils/Drainage - The subgrade soils are mostly Silt Loam with some Loam and Sand Loam. The design "R" value was determined to be 15.

Traffic - Traffic for the year 2011 is forecasted to be 8,000 (AADT) for the 7.5 mile (12.1 km) segment between T.H. 63 and T.H. 52 and 16,300 for the 4.7 mile (7.56 km) segment east of T.H. 52. The twenty year design CESAL's was 9,375,000.

New Construction - The eastbound lanes were overlaid with 1 inch (2.54 cm) thick by 33 feet (10.1 m) wide Permeable Asphalt Stabilized Base Stress Relief Course (Mn/DOT Spec. 2331). The JPCP overlay was 8 inches (20.3 cm) thick west of T.H. 52 and 9 inches (22.9 cm) thick east of T.H. 52. The 27 foot (8.23 m) wide concrete pavement had 15 foot (4.57 m) effective random joint spacing. The dowels were 15 inches (38 cm) long and had a 1 inch (2.54 cm) diameter. Edge drains and interceptor drains (mini weeps) were installed on this project.

Present Condition - Data not yet available.

Lessons Learned - See SP 0980-127

I 90
SP 5380-94
Year Built - 1992

Location - Westbound lanes, near Adrian, from West Nobles Co. Line to C.S.A.H. 35, just west of Adrian. (5.4 miles, (8.69 km) RP 20.5 to 26.0)

Original Conditions - This segment of I-90 was originally graded in 1964. Subcuts ranging from 3.0 to 4.5 ft (0.91 - 1.37 m) were backfilled with granular material. The aggregate base consisted of 3 inches (7.62 cm) of Class 5 and 3 inches (7.62 cm) of Class
4 aggregate base. The roadway was then paved in 1966 with 8 inches (20.3 cm) of continuously reinforced concrete pavement. In 1980, the joints and cracks were repaired and the shoulders were replaced on this stretch of I-90. In 1987, edge drains were installed.

Soils/Drainage - R-values ranged from 11.2 to 15.3 with an average R-value of 12.0 and a design R-value of 11.0.

Traffic - Two-way AADT is 6826 for the year 2011. The twenty year design CESAL's was 7,037,000.

New Construction - The two westbound lanes were overlaid with a 1 inch (2.54 cm) thick Permeable Asphalt Stabilized Stress Relief Course (PASSRC) (Class A material, CA-70 Aggregate) followed by 8 inch (20.3 cm) thick of non-reinforced concrete pavement. The JPCP overlay is 27 feet (8.23 m) wide and has doweled joints with an effective random joint spacing of 15 feet (4.57 m). The dowels were 15 inches (38 cm) long and had a 1 inch (2.54 cm) diameter. Edge drains were placed and interceptor drains were constructed in the outside and inside shoulders and along any areas where the pavement has been cracked.

Present Condition - Data not yet available.

Lessons Learned - See SP 0980-127

I 35
0980-127
Year to be Built - 1993

Location - Northbound lanes, near Moose Lake, from Jct TH 73 to Jct CSAH 4. (10.1 miles, (16.3 km) RP 214.6 to 224.7)

Original Conditions - This segment was paved in 1970 with 9 inches (22.9 cm) of reinforced concrete 24 feet (7.32 m) wide over 4 inches (10.2 cm) Class 5 aggregate base. The northbound lanes were experiencing excessive deterioration. The Condition Ratings for 1992 resulted in a PSR of 3.3, a SR of 2.3 and a PQI of 2.8.

Soils/Drainage - The inplace subgrade has Sandy Loams that were given a 2 feet (0.61 m) compaction subcut except in problem areas where it was increased to 3.75 feet (1.14 m). A design R value of 15 was calculated for use in the pavement design.

Traffic - The predicted ADT is 17,000 for the year 2011. The twenty year design CESAL's was 7,750,000.

New Construction - The northbound lanes will be paved with a 1 inch (2.54 cm) thick Permeable Asphalt Stabilized Base (PASB) 31 feet (9.45 m) wide meeting the requirements of (2331) Bit Mix For Stress Relief Course, followed by 7.5 inches (19.1 cm) of JPCP 27
feet (8.23 m) wide. The pavement will have 15 inch (38 cm)
long, 1 inch (2.54 cm) diameter dowels and a random effective
joint spacing of 15 feet (4.57 m). Edge drains and interceptors
at pavement joints will be provided under this overlay project.

Present Condition – Data not yet available.

Lessons Learned –

1. Standard guidelines for Unbonded Concrete Overlays are
developed for use statewide. See Attachment 1.

Findings

Unbonded concrete overlays have proved to be a cost effective way
of rehabilitating concrete pavements. The design has developed
gradually since the first overlay was constructed near Olivia in
1977. However, thickness design has not significantly changed
during the same time period. The method used currently is
contained in Attachment 2. Most of the changes have been in
construction practices and design details. The following findings
are considered significant and therefore should be used when
designing all future unbonded concrete overlays.

1. The pavement must be green sawed to 1/3 the thickness (t)
of the pavement, as shown in the design procedure
attachment, to insure proper joint performance. Joints
sawed to a depth of t/4 did not initially crack at every
joint. The joints that did crack opened as much as two
inches (5 cm), however all of the joints eventually did
crack within about one year. Decreasing the amount of AC
in the mix for the stress relief course and not cutting
the existing CRC pavement also helped joint performance.

2. The 1 inch thick stress relieving layer has performed
well. The increased depth of saw cut versus the depth
required for normal paving is an example of just how
effective it is in reducing frictional stresses.

3. The switch to a drainable stress relieving layer has also
proved successful. Performance to date has been good,
their are no significant constructability problems, and
we have the added benefit of improved drainage. The
improved drainage should reduce the incidence of D-
cracking and mortar deterioration.

4. The widened section has not shown any increased distress
in the area where it is "cantilevered" over the existing
slab. The rumble strips combined with the 12 foot
striping appear to be keeping heavy wheel loads off the
edge of the pavement.
5. The drainage system has developed to the point where few modifications are expected. The stress relief/drainage layer, interceptor (mini-weep) drains, and edge drains combine to provide effective drainage to the unbonded concrete overlay.

6. The skewed contraction joint dowel assembly needs to be securely anchored to prevent any movement. Anchors are driven into the existing pavement a minimum of one inch as shown in attachment. This need became apparent when the stress relief layer was switched to the open graded drainable material.

7. A new lug anchor design was developed for unbonded concrete overlays primarily due to the fact that the pavement slid much easier on the stress relief layer. Number 8 bars are drilled into the existing pavement as shown in Attachment 1.

8. The transition from the unbonded overlay to on-grade pavement has been revised. The expansion joint has been removed and replaced with a "hinge" joint. This detail is shown in the design procedure, Attachment 2.

9. The 15 foot effective, skewed, doweled, and plain design is performing well. The Structural Rating (SR) for each of the overlays is currently 4.0, or no defects. On average the unbonded overlays are outperforming on-grade concrete pavements, see Figure 1. The Present Serviceability Rating, (PSR) or ride for standard concrete pavement built on-grade over the same time period had similar ratings, see Figure 2. This data was taken from Mn/DOT's pavement management system and is considered to provide a good comparison of the two types of concrete pavement.

10. A special effort is not generally made to stagger joints in the field a minimum of three feet although it is recommended in the design guidelines.

11. Unbonded concrete overlays cost around $350,000 per two lane mile as compared to about $500,000 for reconstructed concrete pavements under similar conditions. Unbonded concrete overlays are designed for a 30 year life and reconstructed concrete pavements are designed to last 35 years. (The 30 year design life is the result of an "expert" panel formed by Mn/DOT and is not based on any performance data.) This design is for thickness only, everything else is identical.
12. The construction sequence developed for the construction of unbonded overlays is considered crucial to their overall success. The construction sequence should consist of the following operations in order:

1) Clean in place pavement and shoulders.
2) Install mini-weep drains.
3) Install stress relief/drainage layer.
4) Pave unbonded overlay.
5) Install pavement edge drains.
6) Pave new bituminous shoulder.

This procedure should help prevent any undermining of the new unbonded overlay by the edge drain trenching operation.

Recommendations

Unbonded concrete overlays can be designed to perform as well as the standard rigid pavements Mn/DOT currently constructs. The unbonded concrete overlay policy (Attachment 3) sets limits on where Mn/DOT currently recommends their use. This policy, the letter containing the standard guidelines and the design procedure should be followed when designing and constructing these pavements. Exceptions should only be granted after consultation with the Manager of the Pavement Engineering Section.

The life of any concrete pavement depends greatly on the quality of the aggregate used in its construction. The drainage system included in unbonded overlays should help resist damage to reactive and/or D-cracking susceptible aggregates, but deterioration will continue in the underlying pavement. This deterioration should be monitored for its effect on the concrete overlay. Consideration should also be given to using only the most durable aggregates available.

Construction practices are also critical to the performance of unbonded overlays. Structures that are expected to last 35 years under harsh conditions need to be constructed with care. Unique construction procedures and details developed over the years for unbonded concrete overlays must be followed to insure predicted performance.

The data obtained from the PaveTech van will be critical in the further examination of these overlays. It has provided valuable baseline data on the pavements constructed in 1992 and with more data from future runs it will enable us to build better prediction models. A detailed analysis of data gathered in the Fall of 1992 will be reported on in the final report.
Summary

Based on the eleven projects constructed to date in Minnesota we have concluded that unbonded concrete overlays provide the designer with another cost effective method of extending pavement life. Like any rehabilitation strategy they work best under certain conditions. Additional data gained from the survey completed with the PaveTech equipment will help us refine the design further. Thus far, the unbonded overlays appear to be performing near the levels of new or reconstructed rigid pavements and at a lower cost. The true test of a concrete pavement is time, especially when D-cracking is considered. However, based on what we have learned to date on these eleven projects we feel that our current designs will pass that test.
REFERENCES

1. Voigt, G.F., Michael I. Darter, and Sam Carpenter, Field Performance Review of Unbonded Jointed Concrete Overlays, Transportation Research Record 1227,


Figure 1
Unbonded vs. On-grade Concrete Pavement Surface Rating

SR
4.2
4
3.8
3.6
3.4
3.2
3
0 2 4 6 8 10
Years in Service

On-grade Unbonded

All data taken from Mn/DOT's PMS.
All unbonded overlays included except TH 71.
Figure 2
Unbonded vs. On-grade Concrete Pavement
Present Serviceability Rating

PSR

4.5

4

3.5

3

2.5

0  2  4  6  8  10

Years in Service

On-grade  Unbonded

All data taken from Mn/DOT's PMS.
All unbonded overlays included except TH 71.
STATE OF MINNESOTA
OFFICE MEMORANDUM

DEPARTMENT: Transportation
Materials and Research Laboratory
1400 Gervais Ave.
Maplewood, Mn. 55109

DATE: August 16, 1991

TO: Rod Garver, Materials Engineer
District 1, Duluth

FROM: David L. Rettner, Assistant Concrete Engineer

PHONE: 779-5575

SUBJECT: Standard Guidelines for Unbonded Concrete Overlays

Please use the following guidelines when designing any future unbonded concrete overlays on I-35.

1) All pavement should be non-reinforced, 15 foot effective joint spacing, 27 feet wide, including where the in place pavement is removed for bridge approaches and underpasses.

2) All transverse joints should be C4D-Modified and should conform to the attached detail (\( g = \frac{t}{3}\) for unbonded pavements).

3) Use the attached dowel basket assembly detail and anchoring procedure. This modified basket will anchor to the bond-breaker better than the standard basket.

4) Use the attached lug anchor design in areas with a grade greater than 3%. The pavement tends to slide more with the asphalt treated layer under it.

5) The construction sequence should consist the following operations in order:
   1) Clean in place pavement and shoulders
   2) Install mini-weep drains
   3) Install stress relief/drainage layer
   4) Pave unbonded concrete overlay
   5) Install pavement edge drains
   6) Pave new bituminous shoulder

Note: The in place shoulder should be left intact to provide a paving platform and to provide consistent density under the widened section of the overlay.

The use of these guidelines should aid in simplifying the design procedure.
FILL WITH SILICONE JOINT SEALER

BACKER ROD MUST BE 1/8" WIDER THAN JOINT

FINAL SAW CUT 3/8" X 1-1/4"

TRANSVERSE PAVEMENT JOINT C4 AND C4D MODIFIED
SECTION "A" - "A"

CONTRACTION JOINT DOWEL ASSEMBLY NOTES:

1. 1-1/4" X 15" EPOXY DOWEL SHEARED AT BOTH ENDS.

STEEL FOR DOWEL SHALL COMFORM TO AASHTO SPEC. M31 FOR GRADE 40 (10 MIl. AFTER CURE).

EPOXY FOR DOWELS SHALL COMFORM TO ASTM SPEC. M254, TYPE B. (5 TO 10 MIl. AFTER CURE).

A MINIMUM OF SEVEN (7) ANCHORAGE POINTS ARE REQUIRED, FOUR ON THE SIDE OF THE BASKET FACING THE FRONT OF THE PAVER.

THE DOWEL BASKET ASSEMBLIES SHALL BE ANCHORED TO THE UNDERLYING CONCRETE PAVEMENT TO PREVENT ASSEMBLY MOVEMENT. THE ANCHORAGE SYSTEM SHALL BE TO USE PINS OR FASTENERS OF SUFFICIENT LENGTH AND SHANK DIAMETER (0.177 INCH MINIMUM) TO PENETRATE INTO THE INPLACE CONCRETE A MINIMUM OF 1 INCH. THE CONTRACTOR'S CHOSEN ANCHORAGE PROCEDURE MUST BE DEMONSTRATED PRIOR TO THE START OF PAVING TO THE SATISFACTION OF THE ENGINEER.
Lug Anchor Design for Unbonded Overlay
Spaced @ 195' on 3% or Greater Grade

Top of Inplace Slab Shall be Clean and Free of All Foreign Material. Apply an Approved grout immediately Before Concrete.

Lugs Shall Be Placed A Minimum of 3' from an Existing Joint or Crack.

Each Lug Anchor:
14 #5 Straight 3'-8"
28 #8 Bent 2'-6"
All Bars Epoxy Coated
Lug Anchor Design for Unbonded Overlay

Inplace Slab

Space at 20"

--- 28 Bent #8 Bars
--- 14 Straight #5 Bars

#5 Bars Shall be Tied to #8 Bars to Prevent Shoving

24'-0"

Plan View
MINNESOTA DEPARTMENT OF TRANSPORTATION
UNBONDED CONCRETE OVERLAY DESIGN PROCEDURE

12/14/92
DRAFT

An unbonded JPCP overlay of an existing JPCP, JRCP or CRCP pavement can be placed to improve both structural capacity and functional condition.

Feasibility

An unbonded overlay is a feasible rehabilitation alternative for PCC pavements for practically all conditions. However, a PCC unbonded overlay would not be feasible under the following conditions where:

1. The amount of deteriorated slab cracking and joint spalling is not large and other alternatives would be much more economical.

2. Vertical clearance of bridges is inadequate for required overlay thickness. This may be addressed by reconstructing the pavement under the overhead bridges or by raising the bridges. Thicker unbonded overlays may also necessitate raising signs and guardrails as well as steepening side slopes and extending the culverts.

3. The existing pavement is susceptible to large heaves or settlements.

4. Short segments of alignment changes are involved.

5. The existing pavement is an urban design with curb and gutter.

Pre-Overlay Repairs

One major advantage of an unbonded overlay is that the amount of repair to the existing pavement prior to overlay is minimized. However, unbonded overlays are not intended to bridge localized areas of nonuniform support. The following types of distress should be repaired prior to placement of the overlay to prevent reflection of cracks that may reduced its service life:
<table>
<thead>
<tr>
<th>Distress Type</th>
<th>Repair</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working crack</td>
<td>- No repair needed</td>
</tr>
<tr>
<td>Punchout/Badly</td>
<td>- Full-depth repair</td>
</tr>
<tr>
<td>shattered slabs</td>
<td></td>
</tr>
<tr>
<td>Spalled joints</td>
<td>- No repair needed</td>
</tr>
<tr>
<td>Pumping</td>
<td>- Edge drains</td>
</tr>
<tr>
<td>Settlement</td>
<td>- Level-up with Asphalt CementConcrete</td>
</tr>
<tr>
<td>Poor Joint/Crack</td>
<td>- No repair needed; if pavement has many joints or cracks with poor load transfer, consider a thicker stress relief layer.</td>
</tr>
<tr>
<td>Load transfer</td>
<td>- Full-depth repair</td>
</tr>
<tr>
<td></td>
<td>- Seat</td>
</tr>
<tr>
<td>High Deflections</td>
<td>- Fill with bituminous patching material</td>
</tr>
<tr>
<td>Unstable slabs</td>
<td></td>
</tr>
<tr>
<td>Extensive D-cracking</td>
<td></td>
</tr>
</tbody>
</table>

**Design Methods**

The design concept for unbonded overlays is based on providing an overlaid pavement such that the base slab plus the unbonded resurfacing is structurally equivalent to a new full-depth concrete pavement designed to carry the anticipated future traffic. This implies that the resurfaced pavement will provide a service life that is equivalent to that provided if a new full-depth concrete pavement were to be constructed.

Two thickness design methods will be presented and are as follows:

A. Corps of Engineers (COE) Design Method  
(This method was empirically developed.)

\[ D_{OL} = \sqrt{D_{N}^2 - CD_{E}^2} \]

\[ D_{OL} = \text{required overlay thickness, inches} \]

\[ D_{N} = \text{required thickness for new full-depth pavement, inches} \]

\[ D_{E} = \text{thickness of existing pavement, inches} \]

\[ C = \text{Coefficient depending on the structural condition of the existing pavement determined by visual inspection. The practice has been to use the following values for } C; \text{ however, other values can be used.} \]
C = 1.0  Existing pavement is in good overall structural condition with little or no cracking.

C = 0.75  Existing pavement has initial joint and corner cracking due to loading but no progressive structural distress or recent cracking.

C = 0.35  Existing pavement is badly cracked or shattered structurally.

B. PCA Method

This procedure was mechanistically derived and is based on results of pavement analyses conducted using the finite element computer program JSLAB.

Stress data developed using program JSLAB were used to prepare design charts for determination of unbonded overlay thickness. These charts are applicable to existing concrete pavements that have effective modulus of elasticity values ranging from about 3,000,000 to about 4,000,000 psi.

Design charts are presented for three cases of existing pavement condition. These cases are as follows:

1. Existing pavement exhibits a large amount of midslab and corner cracking with poor load transfer at joints and cracks.

2. Existing pavement exhibits a small amount of midslab and corner cracking. It exhibits reasonably good load transfer at the joints and cracks. Localized repairs were performed to correct distressed slabs.

3. Existing pavement exhibits a small amount of midslab cracking and good load transfer at the cracks and joints.

The design chart for Case 1 was developed using data from analysis of overlay sections containing a crack in the existing pavement directly under an edge load on the overlay. The design chart for Case 3 was developed using data from the analysis of overlay sections with no cracking in the existing pavement. The design chart of Case 2 was developed through interpolation between Case 1 and Case 3 conditions. The design charts are given in Figures 1, 2, and 3 for Cases 1, 2, and 3; respectively.

The first step in the design process involves determination of the thickness of a full-depth new concrete pavement that would be needed for the anticipated future traffic.
Design charts in Figures 1, 2 and 3 are then used to compute the thickness required for the unbonded overlay.

Representative values of resurfacing thickness determined from Figures 1, 2, and 3 are summarized in Table 1. These thicknesses are listed for different values of existing pavement thicknesses and equivalent full-depth concrete pavement thickness. The determination of the actual overlay thickness is influenced by the condition and thickness of the existing base pavement.

To compare results given by the design charts with the Corps of Engineers design equations for unbonded overlay, overlay thicknesses were computed for values of pavement condition coefficient, C, of 0.35, 0.6, and 0.8. These results are presented in Table 2. It is seen that the overlay thicknesses listed in Table 2 agree closely with those listed in Table 1. This indicates that the characterization of the existing pavement in terms of Cases 1, 2, and 3, as recommended in the design procedure, closely simulates existing pavement condition coefficient, C, values of 0.3 to 0.5, 0.5 to 0.7, and 0.7 to about 0.9, respectively.

In comparing these two design methods, it can be observed that the ratings (Cases 1, 2 and 3 and C factors) involved a certain degree of subjectivity. Because of the subjectivity involved, various engineers may rate a pavement differently and thereby obtain different thickness for the overlay.

Overlay Design Procedure

The design process will consist of the following:

1. Existing pavement evaluation.
   a. Pavement condition survey.
      Utilize the PMS data relative to ride and distresses. The type, extent and severity of the distresses should be identified. The pavement should be divided into analysis sections based on pavement design, construction history, traffic usage and location.

   b. Pavement Design.
      1) Type of pavement (JPCP, JRC, CRC)
      2) Slab thickness
      3) Type of load transfer
      4) Type of shoulder (tied, PCC, other)

   c. FWD Testing.
      FWD load testing should be considered when there exists load and material related distresses. The load testing should be carried out to determine the severity of the problem. The load testing should be conducted at joints and cracks to determine relative deflection across joints and cracks. Results of load
testing can be used to establish if load transfer across joints and cracks is adequate. The deflection data in turn can be used for determination of the Case and C factor to be used for design.

2. Traffic Analysis
In accordance with current policy unbonded overlay thickness designs will be based on anticipated cumulative 30-year design lane rigid ESALs.

The 30-year design lane rigid ESALs (CESALs) should be determined as follows:

\[ CESAL_{30} = CESAL_{20} + 10 \left( \frac{CESAL_{35} - CESAL_{20}}{15} \right) \]

\[ CESAL_{20} = \text{Rigid ESAL's shown for the Design Year in the Office of Transportation Data Analysis, Traffic Forecast and Analysis Sections "Cumulative ESAL Report."} \]

If the design year is moved back a year or two, the new design year ESALs should be used for CESAL\textsubscript{20} and the CESAL\textsubscript{35} shown in the "Report" should be revised as follows:

\[ CESAL_{35r} = CESAL_{35} + (CESAL_{20r} - CESAL_{20o}) \]

\[ CESAL_{20r} = \text{New Design Year Traffic} \]

\[ CESAL_{20o} = \text{Original Design Year Traffic} \]

(Round CESAL\textsubscript{30} values up to the nearest 500,000.)

Example:
Base Year 1993

<table>
<thead>
<tr>
<th>Year</th>
<th>CESALs</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>15,017,000</td>
</tr>
<tr>
<td>2014</td>
<td>15,312,000</td>
</tr>
<tr>
<td>2015</td>
<td>15,608,000</td>
</tr>
<tr>
<td>2028</td>
<td>29,538,000</td>
</tr>
<tr>
<td>a. Design Year 2013</td>
<td></td>
</tr>
</tbody>
</table>

\[ CESAL_{30} = 15,017,000 + 10 \left( \frac{29,538,000 - 15,017,000}{15} \right) \]

\[ CESAL_{30} = 25,000,000 \]
b. Design Year moved 2013 to 2015
\[ CESAL_{35R} = 29,538,000 + (15,608,000 - 15,017,000) \]
\[ CESAL_{35R} = 30,500,000 \]
c. Design Year 2015
\[ CESAL_{30} = 15,608,000 + 10 \left( \frac{30,129,000 - 15,608,000}{15} \right) \]
\[ CESAL_{30} = 25,500,000 \]

C. Subgrade Support (Modulus of subgrade reaction - k.)
   a. Design R-Value (Average minus one standard deviation)
   b. \( k = 1.17 + 63 \sqrt{R} \)

D. Full-Depth Concrete Pavement Thickness - \( D_N \)
   Use PAVE program with following parameters:
   a. Design R-Value
   b. 30-year design lane traffic - \( CESALS_{30} \times 0.93 \)
      (Modified for frozen subgrade effect.)
   c. \( P_v = 2.5 \)
   d. Modulus of rupture - 508 psi
   e. Modulus of elasticity - 4,200,000 psi
   f. J-Factor
      1) \( J = 2.6 \) for 27-foot wide pavement
      2) \( J = 3.2 \) for 24-foot wide pavement

E. Overlay Thickness
   1. COE Method

   \[ D_{OL} = \sqrt{D_N^2 - C D_E^2} \]

   \( D_N \) - From PAVE program (do not round)
   \( D_E \) - existing slab thickness
   \( C \) - Coefficient previously design (Badly D-Cracked pavements use \( C = 0.5 \), unless FWD load testing indicates that the load transfer across joints and cracks is adequate.)
2. PCA Method

Use design charts in Figures 1, 2, and 3 to determine the required unbonded overlay thickness. (Badly D-Cracked pavements use Case 1, unless FWD load testing indicates that the load transfer across joints and cracks is adequate.)

3. Design Thicknesses

a. Use both methods and average the results.
b. Round the results in accordance with the current rounding procedures and use this value for the design thickness. However, the minimum design thickness should be in accordance with the following:

<table>
<thead>
<tr>
<th>Overlay Width (ft.)</th>
<th>27</th>
<th>24</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing Pavement Width (ft.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>6&quot;</td>
<td>*</td>
</tr>
<tr>
<td>24</td>
<td>7&quot;</td>
<td>6&quot;</td>
</tr>
<tr>
<td>22</td>
<td>*</td>
<td>7&quot;**</td>
</tr>
<tr>
<td>20</td>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>

* Not appropriate design
** Unless recommended otherwise by MR&E's Concrete and Pavement Design Units.

F. Other Design Appurtenance/Considerations

1. Pavement Type

All unbonded concrete pavement will be designed as jointed plain concrete pavements (JPCP) unless otherwise determined by MR&E's Concrete and Pavement Design Units.

2. Transverse Joints

All transverse joints shall be dowelled as follows:

a. All transverse joints shall be doweled, using 1-inch dowels for pavements less than 9 inches thick and 1.25-inch dowels for pavements greater than or equal to 9 inches in thickness.
b. Pavements 7 inches or greater use a 15-foot effective (13, 16, 14, 17) spacing.
c. Pavements less than 7 inches, contact the MR&E's
Concrete and Pavement Design Units for the appropriate joint spacing.

d. Do not locate transverse joints within 3 feet of an existing transverse joint or working crack. The most effective joint location is to place the overlay joint on the approach side of an existing joint or crack. This allows the leave slab to bridge the joint or crack and avoid cantilever deflections and pumping action beneath the existing (APCA).

e. All transverse joints should be C4D-Modified and should conform to Figure 4 ($g = \frac{1}{3}$).

f. Dowel basket assembly detail and anchoring procedures should be in accordance with Figure 5.

g. Transition from unbonded overlay to on grade pavements near bridges and other removal areas and associated supplemental steel detail should be in accordance with Figures 6 and 7.

3. Joint Sealant

   a. Use hot pour (3720) for longitudinal joints.

   b. Use silicone for transverse joints.

4. Rumble Strips

   Provide on 27-foot wide pavement but not on a 24-foot wide pavement.

5. Stress Relief Layer

   Provide a 1-inch minimum stress relief layer between the unbonded overlay and the existing pavement. The material used for the layer should be in accordance with (2331) Type 31 BIT MIX FOR PERMEABLE STRESS RELIEF COURSE (SP 4-107). This layer should be 28 and 31-feet wide for a 24 and 27-foot wide overlay, respectively; extending out from the concrete pavement edge 2-feet on each side or as needed to support paver tracks (Figure 9). If the inplace pavement is badly faulted the stress relief layer should be increased in thickness and placed in two lifts.

6. Interceptor Drain

   Provide interceptor drains when the overlay pavement is wider than the existing underlying pavement. The drains should be in accordance with Figures 8 & 9.

7. Pavement Edge Drain

   Provide edge drains for all pavements regardless of subgrade soil type in accordance with Figure 9. Edge
drains are to be provided, even for granular subgrade type soils, since the stress relief layer consists of a permeable stabilized material.

8. Extensive D-Cracking

Provide for the removal of unconfined and/or loose deteriorated concrete at the pavement joints, cracks and patches by air blasting and power sweeping. Air blasting shall utilize a nominal 100 psi pressure as directed by the Engineer. Depressions, which result from air blasting and/or power sweeping, at the transverse and longitudinal joints and cracks shall be patched with Bituminous Patching Mixture 2231 as directed by the Engineer. Patching of these areas shall be accomplished prior to paving the stress relief layer and compacted with a pneumatic tired roller.

G. Design Example

1. Design Information
   a. Existing Roadway
      - Four-lane divided highway
      - 22 years old
   b. Existing Pavement
      - 9.0-inch JRCP
      - 5.0-inch granular subbase
      - 40-foot joint spacing
      - 24-feet wide
      - dowelled joints
   c. Roadbed Soils
      - Clay loam
      - Design R-Value = 15
   d. Major Distresses
      - Mid-panel cracks
      - Joint deterioration (severely D-Cracked)
      - PSR = 2.7
      - PQI = 2.6
   e. Traffic
      \( \text{CESAL}_{30} = 25,000,000 \) from previous example
   f. Proposed Design
      - 15-foot effective joint spacing
      - all joints dowelled
      - 27-foot wide pavement

2. New Pavement for anticipated traffic
   - Design R-Value - 15
   - \( J = 2.6 \)
   - \( M_r = 500 \) psi
   - \( E = 4,200,000 \) psi

9
- $P_1 = 2.5$
- $CESAL_{50} = 25,000,000 \times 0.93^* = 23,250,000.$
  * 0.93 - frozen subgrade effect

PAVE program results in a new full-depth pavement of 9.7 inches - $D_w$.

3. Overlay Thickness
   a. COE Method
      
      $$D_{OL} = \sqrt{D_N^2 - CD_E^2} = \sqrt{9.7^2 - 0.5(9.0)^2} = 7.3 \text{ inches}$$

   b. PCA Method
      Figure 1 (Case 1), $D_{OL} = 8.2 \text{ inches}$

Average of Methods $(7.3 + 8.2) / 2 = 7.8 \text{ inches}$

Design Pavement 8.0 inches thick

The above design procedures were derived from:


FHWA's "Techniques for Pavement Rehabilitation" developed by ERES Consultants, Inc.


Table 1. Representative Values of Resurfacing Thickness.

<table>
<thead>
<tr>
<th>t_n' in.</th>
<th>t_e in.</th>
<th>Resurfacing Thickness, in</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Case 1</td>
</tr>
<tr>
<td>8</td>
<td>8</td>
<td>6.8</td>
</tr>
<tr>
<td>7</td>
<td>7</td>
<td>7.2</td>
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<td>6</td>
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</tr>
<tr>
<td>10</td>
<td>9</td>
<td>9.0</td>
</tr>
<tr>
<td>8</td>
<td>9.2</td>
<td>7.8</td>
</tr>
<tr>
<td>7</td>
<td>9.4</td>
<td>6.8</td>
</tr>
<tr>
<td>12</td>
<td>9.5</td>
<td>11.5</td>
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<tr>
<td>8</td>
<td>11.7</td>
<td>10.8</td>
</tr>
<tr>
<td>7</td>
<td>11.8</td>
<td>11.2</td>
</tr>
</tbody>
</table>

Notes: t_n = equivalent full depth new pavement thickness
t_e = existing pavement thickness
Cases 1, 2 and 3 refer to condition of existing pavement described in the text.
Values in parentheses indicate minimum thickness requirement of 6 in.

Table 2. Resurfacing Thickness Determined Using Corps of Engineers' Equation.

<table>
<thead>
<tr>
<th>t_n' in.</th>
<th>t_e in.</th>
<th>Resurfacing Thickness, in</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>c = 0.35</td>
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<tr>
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<td>11.0</td>
</tr>
<tr>
<td>7</td>
<td>7</td>
<td>11.3</td>
</tr>
</tbody>
</table>

Notes: t_n = equivalent full depth new pavement thickness
t_e = existing pavement thickness
c = pavement condition coefficient
Values in parentheses indicate minimum thickness requirement of 6 in.
Figure 1: Design Chart for Case 1 Condition of Existing Pavement
Figure 2. Design Chart for Case 2 Condition of Existing Pavement
Figure 3  Design Chart for Case 3 Condition of Existing Pavement
FILL WITH SILICONE JOINT SEALER

BACKER ROD MUST BE 1/8'' WIDER THAN JOINT.

1) FINAL SAW CUT 3/8'' X 1-1/4''

TRANSVERSE PAVEMENT JOINT C4 AND C4D MODIFIED
CONTRACTION JOINT DOWEL ASSEMBLY NOTES:

1-1/4' X 15' EPOXY DOWEL SHEARED AT BOTH ENDS.

STEEL FOR DOWEL SHALL COMFORM TO AASHTO SPEC. M31 FOR GRADE 40 (10 MIL. AFTER CURE).

EPOXY FOR DOWELS SHALL COMFORM TO ASTM SPEC. M254, TYPE B (5 TO 10 MIL. AFTER CURE).

A MINIMUM OF SEVEN (7) ANCHORAGE POINTS ARE REQUIRED, FOUR ON THE SIDE OF THE BASKET FACING THE FRONT OF THE PAYER.

THE DOWEL BASKET ASSEMBLIES SHALL BE ANCHORED TO THE UNDERLYING CONCRETE PAVEMENT TO PREVENT ASSEMBLY MOVEMENT. THE ANCHORAGE SYSTEM SHALL BE TO USE PINS OR FASTENERS OF SUFFICIENT LENGTH AND SHANK DIAMETER (0.177 INCH MINIMUM) TO PENETRATE INTO THE INPLACE CONCRETE, A MINIMUM OF 1 INCH. THE CONTRACTOR'S CHOSEN ANCHORAGE PROCEDURE MUST BE DEMONSTRATED PRIOR TO THE START OF PAVING TO THE SATISFACTION OF THE ENGINEER.

Figure 5
TRANSITION FROM UNBONDED OVERLAY TO ON GRADE PAVEMENT
(USE NEAR BRIDGES AND OTHER REMOVAL AREAS)

C-4 JOINT SAWED PERPENDICULAR TO CENTERLINE JOINT

16 - #6 BARS
SPACED @ 8 INCHES C-C

C4D JOINT

APPROX. 7.5'

APPROX. 7.5'

INPLACE PAVEMENT

1" MINIMUM PASB

7.5"

100' TAPER SECTION

4" PASB

4.5" CL 5

X"
SUPPLEMENTAL STEEL DETAIL

DIRECTION OF TRAFFIC

C4 JOINT CUT
PERPENDICULAR TO CENTERLINE

16 - #6 BARS @ 8" C-C

3 - #4 BARS @ 2' C-C

12" MINIMUM

3 - #4 BARS @ 2' C-C

12'
INTERCEPTOR DRAIN DETAIL

NOTE:
① SEE SPECIAL PROVISIONS FOR MATERIAL AND CONSTRUCTION DETAILS

Figure 8
SUBSURFACE DRAIN, PERMEABLE BASE & DRAIN
USED WITH PASSRC 1 2

NOTES:
1 PERMEABLE ASPHALT STABILIZED STRESS RELIEF COURSE
2 SEE SPECIAL PROVISIONS FOR PERMEABLE BASE DRAIN & PASSRC MATERIAL AND CONSTRUCTION DETAILS
3 WIDTH AS NEEDED TO SUPPORT PAVEMENT TRACK
4 PERMEABLE AGGREGATE TO BE HEAPED 2" ABOVE TOP OF PASSRC AFTER COMPACTION
5 INTERCEPTOR DRAINS TYPICALLY USED AT THIS LOCATION; SEE DETAIL & SPEC. PROVISIONS IF APPLICABLE
6 IF THE BIT. SHLDR. REMAINS IN PLACE, THE PASSRC AND SHLDR. CAN BE REMOVED BY MILLING, TRENCHING, OR OTHER METHOD, PROVIDED THE REMAINING BIT. SHLDR. IS NOT DISTURBED/DISPLACED

Figure 9
POLICY ON UNBONDED OVERLAYS
RELATING TO PAVEMENT SELECTION

The initial step is to determine the feasibility of an Unbonded Overlay. An Unbonded Overlay (new concrete over an existing concrete pavement) is not feasible if one of the following conditions is met:

1) **Short segments** - Projects often have areas which require regrading or pavement removal due to:
   a) Clearance at bridges
   b) Alignment (vertical or horizontal) changes
   c) Subgrade corrections

   When these areas become a significant portion of the overall project, the use of an unbonded overlay between these segments should be discouraged.

2) **Urban design** - In urban areas, with curb and gutter design, unbonded overlays should not be used.

If the Unbonded overlay is feasible and the project is programmed in the Reconstruction or Major Construction category, the district may submit the Unbonded Overlay as an alternate design. The district should state this desire clearly in their submittal.

The Unbonded Overlay and interim fixes will be designed by the Pavement Design Engineer. The interim fixes should be that of a joint seal at year 15, and a thin overlay at year 30. This thin overlay is given a life of 5 years, to get the same 35 year analysis period for all alternatives.

The Estimating unit will then do their analysis of the five alternatives, including both initial costs and interim costs.

The general policy of the Pavement Selection Committee will be:

- If the low is Unbonded, and the second low is Rigid, the district may be given the option of the Unbonded or the new Rigid.
- If the low is Unbonded, and the second low is one of the bituminous options, the unbonded overlay will be mandatory.